Credit Seminar On

STATUS AND MANAGEMENT OF SMALL PELAGIC FISHERIES OF INDIA

Submitted By

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Summary

Small pelagics are diverse group of planktivorous fishes, attain maximum length of <35 centimeters and maximum weight of <500 grams and inhabit usually above the continental shelf, about 119 species of small pelagics belonging to 8 families and 32 genras have been reported from Indian waters, off which around 50 species supports major fisheries. Small pelagics, with an annual average of 7.33 lakh tonnes formed 50.9% of the total pelagic catches and 26.9% of the total marine catch of India during 1991 to 2012. Average annual small pelagic fish production increased from low of 4.74 lakh tonnes during 1994 to 11.92 lakh tonnes during 2012. Over last 22 years, marine fish production increased by 76% and small pelagic catches increased by 151%, growth rate in the production of pelagic fisheries has been conspicuously higher than that of the overall production. Small pelagics of commercial bearing are mainly the oil sardine, lesser sardines, anchovies and whitebaits and Indian mackerel, together contributed 99.41 % to the small pelagics and remaining 0.59% by half beaks and full beaks, flying fishes, other mackerels and unicorn cod. During 1991 to 2012, the oil sardine, other sardines, anchovies and whitebaits and Indian mackerel contributed 11%, 3%, 4% and 6% to the total marine fish landings and 14%, 6%, 9% and 12% to the total pelagics landing of India, respectively. Except flying fishes and unicorn cod, all other small pelagics showed increasing trend. Present study indicated that the stock is under greater fishing pressure than desired.

Introduction:

Extensive and indiscriminate exploitation of marine natural resources, during the last 2 decades is leading to a situation where no more commercial fish stock may be left in the sea by 2050, unless ecosystems are protected and biodiversity is reviewed. The task of understanding the dynamics of large marine ecosystem is complex process and it is required to offer scientific advice to develop management interventions. This is true especially in Indian context where the country endowed with 8118 km of coastal length, 0.5 million km^2 of continental shelf and 2.02 million km^2 of EEZ with a catchable annual marine fishery potential of 3.93 million tonnes, which contribute nearly 40% of the total fish production from the Indian Ocean (CMFRI, 1990-2013).

India has been one among the top 10 fish producing countries of the world since 1960. Currently India occupies the second position, contributing about 5.49% to the world fish production of about 158.0 million tonnes and fish production has increased from 4.16 million tonnes in 1991-1992 to 8.67 million tonnes in 2011-2012 (DAHD&F, 2012-13). The marine fish production in India reached 3.94 million tonnes in 2012 due to mechanization of crafts, motorization of country crafts, commencement of the stay over fishing and improvements in gears and related infrastructure facilities, which were introduced at different periods since 1950's.

Small pelagic fishery resources are one of the major components in Indian marine fish landings. Small pelagic fishery resources consists of oil sardine, lesser sardine, Indian mackerel, anchovies and whitebaits, halfbeaks and fullbeaks, flying-fishes, unicorn cod, fusiliers and silversides etc. The small pelagics of commercial bearing are mainly the oil sardine, lesser sardines, anchovies and whitebaits and Indian mackerel and average annual catch for these groups exceeds more than 1 lakh tonnes which contributes substantially to the economy of Indian marine fisheries. The average estimated landing of small pelagics during last 22 years (1991-2012) was 7.34 lakh tonnes, contributing about 26.94% to the India's marine fish production of about 27.23 lakh tonnes (Table 3).

Small pelagic fishery is basically harnessing a natural resource and therefore its management must anchor on knowledge based interventions generated through close monitoring of their distribution, abundance, exploitation, population dynamics and fluctuations of fish stocks in relation to natural factors and anthropogenic interventions. Though there are inherent problems related to the open access system of the fisheries and socio-economic concerns such as over capitalization, excess fishing capacity and lack of responsible fishing practices, India can sustain marine fish production through rigid fisheries management regimes. The major events that took place over last 22 years (1991-2012) and the research work carried out on small pelagic fisheries from time to time are reviewed here to indicate the historic and current status, prospects, challenges, management strategies and measures to increase and sustain small pelagic fish production.

Concept and composition of small pelagic stocks:

The term 'small pelagic fishes' refers to a diverse group of planktivorous fishes, shows shoaling behaviour, which can attain maximum length of $\leq$ 35 centimeters and maximum weight of $\leq$ 500 grams and inhabit the upper surface/subsurface layer of the water column, usually above the continental shelf with water depth < 200 meter. They show area specific distribution in Indian waters. They respond dramatically and quickly to changes in oceanic climate. Most are highly mobile, plankton based food chains, short lived, highly fecund and some can spawn all year round. These biological characteristics make them highly sensitive to environmental factors. Their dynamics have important economic as well as ecological consequences. They are the forage for larger predatory fishes, sea birds and marine mammals.

In Indian context small pelagics comprises different taxonomic groups, which contribute to their rich species diversity and abundance. From the available information on the distribution of small pelagic fishes along the Indian coast, it could be inferred that there are 119 species of small pelagics. Out of the 119 odd species available, around 50 species belonging to 5 families supports major fisheries and form part of commercial catches, either on regular basis or as seasonal inclusions (Table 1). The important varieties belonging to small pelagic group are clupeoids, formed by oil sardine, lesser sardine, anchovies and whitebaits; mackerels (Scombridae), flying fish (Exocoetidae), half beaks (Hemiramphidae) and full beaks (Belonidae) and unicorn cod (Bregmacerotidae). Among these, groups contributing to more than one lakh tonnes are oil sardine, lesser sardines, anchovies and mackerels. The increase or decrease in annual marine fish production of country largely depends on the success or failure of these groups.

Table 1 Major taxonomic categories of small pelagics and their species diversity

Family	**Group/Species**	**Number of species**
1. Clupeidae*	1. Oil sardine	1
	2. Lesser sardines	12
	3. Rainbow sardines	2
	Total number of sardines	**15**
2. Engraulidae*	1. *Coilia spp.*	5
	2. *Encrasicholina spp.*	3
	3. *Setipinna spp.*	4
	4. *Stolephorus spp*.	7
	5. *Thryssa spp.*	16
	Total number of anchovies and whitebaits	**35**
3. Scombridae*	1. Indian Mackerel	1
	2. Other Mackerels	2
	Total number of Mackerels	**3**
4. Exocoetidae (Flyingfishes)	1. *Cheilopogon spp.*	7
	2. *Cypselurus spp.*	2
	3. *Exocoetus spp.*	2
	4. *Hirundichthys spp.*	3
	5. *Parexocoetus spp.*	3

	Total number of Flyingfishes	**17**
5. Belonidae (Fullbeaks/Needlefishes)	1. *Ablennes spp.*	1
	2. *Platybelone spp.*	1
	3. *Strongylura spp.*	3
	4. *Tylosurus spp.*	3
	Total number of Fullbeaks/Needlefishes	**8**
6. Hemiramphidae (Halfbeaks)	1. *Dermogenys spp.*	2
	2. *Euleptorhamphus spp.*	1
	3. *Hemiramphus spp.*	3
	4. *Hyporhamphus spp.*	8
	5. *Oxyporhamphus spp.*	1
	6. *Rhynchorhamphus spp.*	2
	7. *Zenarchopterus spp.*	6
	Total number of Halfbeaks	**23**
7. Caesionidae (Fusiliers)	1. *Caesio spp.*	6
	2. *Dipterygonotus spp.*	1
	3. *Gymnocaesio spp.*	1
	4. *Pterocaesio spp.*	5
	Total number of Fusiliers	**13**
8. Atherinidae (Silversides)	1. *Atherinomorus spp.*	2
	2. *Atherion spp.*	1
	3. *Hypoatherina spp.*	3
	Total number of Silversides	**5**
Total number of small pelagics		**119**

*Average annual catches exceeds more than 1 lakh tonnes

(Source: http://en.wikipedia.org/wiki/List_of_fishes_of_India)

Table 2 Life history parameters and biological reference points of small pelagics

Species	**L_{max} (cm)**	**L_{inf} (cm)**	**K(yr^{-1})**	**T_{max} (years)**	**L_m (cm)**	**L_{opt} (cm)**	**L_c (cm)**	**L_r (cm)**	**Exploitation rate (E)**	**Natural mortality (M)**
Sardinella longiceps	22	23.2	1.8	1.7	14	14	8	4	0.4	2.31
Sardinella gibbosa	20	21.1	1.2	2.5	13	13	5	4	0.6	2.03

Sardinella albella	23	24.2	1.2	2.5	15	15	5	4	0.5	2.03
Sardinella fimbriata	21	22.1	1.3	2.3	14	13	5	4	0.5	2.08
Sardinella sirm	22	23.2	1.2	2.3	14	14	7	6	0.2	2.03
Sardinella dayii	18	19	1.3	2.5	12	11	10	9	0.2	2.08
Dussumieria hasselti	19									
Stolephorus devisi	10	10.7	1.6	1.7	7	6	3	2	0.5	2.21
Stolephorus waitei	13	13.8	1.3	2.1	9	8	3	3	0.5	2.08
Stolephorus baganensis	8	8.6	1.5	2	6	5	3	3	0.4	2.17
Stolephorus commersonii	10	10.7	1.5	2	7	6	3	3	0.5	2.17
Coilia dussumieri	20	21.1	1.4	2.1	13	13	14	2	0.5	2.12
Rastrelliger kanagurta	30	31.5	1.7	1.8	18	19	14	9	0.7	2.26

(Source: Devaraj *et al.*, 1997**)**

<u>Common features of small pelagic fisheries:</u>

From the historical reviews and current status of small pelagics, it is clear that small pelagic fisheries of India are characterize by (*i)* dominance of Indian oil sardine and Indian mackerel; (ii) highly fluctuating nature of fishery; *(iii)* area specific distribution of dominant species; *(iv)* crucial role of environment; and *(v)* Unique biological characteristics. Interactions among these vital features determine the abundance of small pelagics.

Dominance of two species: Though over 119 species of small pelagics occur along the Indian coast, only two of them, Indian oil sardine (*Sardinella longiceps*) and Indian mackerel (*Rastrelliger kanagurta*) play a very dominant role, not only in pelagic fisheries, but also in entire Indian marine fisheries. These two species together form around 17.96% of average marine fish landings from 1991 to 2012. Adverse effect of any fishery dependent or independent factors on any of these three species would seriously affect the landing of pelagics, therefore, which are highly vulnerable and subject to fluctuations.

Highly fluctuating nature of fishery: The landing pattern of pelagics could be categorized as: *(i)* fisheries which have fluctuated very widely (Indian oil sardine and Indian mackerel); *(ii)* fisheries which have increased landings consistently (lesser sardines, anchovies and whitebaits); and *(iii)* the only fishery which has declined (unicorn cod). The landing of unicorn cod (*Bregmaceros mclellandi*), which is restricted to Maharashtra coast, decreased from 6000 tonnes per year in 1954 to 422 tonnes per year in 2011. In views of consistently declining fishery, the unicorn cod may have been listed as vulnerable and strategies need to be devised to restore its population.

Area specific distribution of dominant species: Another important characteristic of small pelagics is the area specific abundance of dominant species. The fisheries for oil sardine, flying fishes and unicorn cod are restricted to coastal waters of a single geographic zone, i. e. oil sardine to southwest coast between Cape Comorin to Ratnagiri, flying fishes to Coromandel Coast in Tamil Nadu and unicorn cod along Maharashtra coast. Four group/species (Indian mackerel, lesser sardine and whitebaits in the southwest and southeast coasts; and the golden anchovy in the northwest and northeast coasts) form fisheries in two zones.

A full understanding of reasons why distribution and abundance of a few species are restricted to certain well defined sea areas is yet to emerge. Differences in temperature, salinity, tidal oscillations and food regimes are thought to be important factors. The reason for abundance of oil sardine and Indian mackerel populations in the southwest coast are fairly clear. Regular upwelling along the southwest coast leads to dense plankton blooms. Being plankton feeders, oil sardine and mackerel, which form large shoals and require huge quantities of food, find ideal location to forage.

Role of environment: Several environmental parameters are considered to be the determinants of abundance of oil sardine and mackerel. The onset and intensity of monsoon, sunset activity, surface temperature, variations in patterns of coastal currents, sudden increase in salinity, dissolved oxygen, sinking of offshore waters, sea level and availability of nutrients in coastal waters are some of the causative factors believed to play crucial role in determining abundance of oil sardine along southwest coast.

Unique biological characteristics: Though represented by different taxonomic categories, small pelagics, as a group are characterized by certain unique combination of biological features which include formation of large schools, feeding on plankton, fast growth rate and short life span (2-4 years). Most of them are either continuous spawners or have prolonged spawning periods with high fecundity. Many of them are migratory and show shoaling behavior.

Role of small pelagics in marine ecosystem:

In upwelling ecosystems, small pelagic fish species occupy an intermediate trophic level as they feed mostly on phytoplankton and/or zooplankton. They also develop large biomasses, which vary radically in size according to recruitment strength, and which are dominated by one, or several schooling species in a given ecosystem which undergo large inter annual fluctuations in biomass. The role of pelagic fish in upwelling ecosystems mostly depends on trophic flow control, where they might exert a major control on energy flows, both upwards to their predators and downwards to their zooplankton prey (Fréon *et al.*, 2005).

As small pelagic species occupy a mid-trophic position in the marine food web and seem to play an important role in the functioning of the marine ecosystem which forms an important link in food chains as forage fish for many commercially important species of epipelagic predators such as tunas, bill fishes, seer fishes, barracudas, leather jackets, sciaenids, polynemids, Bombay duck and sharks. Their dynamics have important economic as well as ecological consequences. The high values of natural mortality (M) for the small pelagics stocks of oil sardine, other sardines, anchovies and whitebaits are in tune with their fast growth in the first year of life and their role as the main forage (over 90%) of all epipelagic predators (Devaraj *et al.*, 1997).

Means of exploitation:

Traditional canoes, Pablo-type boats and catamarans are fishing crafts used for exploitation of small pelagic resources. They are navigated either manually or mechanically by fitting inboard or outboard engines. In addition to this different size of purse seiners and ring seiners are being used.

There is wide array of gears employed in small pelagic fisheries. The gears used are shore-seine, boat-seine, gillnet and drift gillnet. Among these, shore seine has gradually disappeared, and *Rampani* of Karnataka has been replaced by purse seiners and ring seiners.

Purse seines, ring seines and gill nets of various mesh sizes were introduced latter for exploitation of small pelagic fishery resources. The introduction of purse seine in seventies and ring seine in eighties, and motorization of traditional crafts in early eighties had enhanced small pelagic fisheries production from the currently exploited 0-50/100 meter depth zones at different stages.

Major small pelagic stocks:

Small pelagics occupy an important position in India's marine fisheries. They constituted about 26.92% of the total marine landings during 1991 to 2012. Among the pelagics, the small pelagics were predominant, contributing about 50.93% to the total landings of the total pelagics. Among the small pelagics, the oil sardine, other sardines, anchovies and whitebaits and Indian mackerel were the most predominant (Table 3). The distribution, production, biology and trade aspects of the major small pelagics are summarized below.

Oil sardine:

Distribution*:* The oil sardine is a major inshore small pelagic fish, distributed in narrow belts extending to a distance of 3 km to 20 km from the coast. Their geographic distribution extends widely from Seychelles through Somalia, Africa, Pakistan, India and Indonesia to the Philippines. Along the Indian peninsula, there is greater concentration of the oil sardine stock in the Malabar upwelling zone along the southwest coast between 8°N and 16°N latitudes, although in recent years a new fishery for this species has emerged along the east coast as well.

Means of exploitation*:* Till the close of the 1970s, various artisanal fishing craft operating gears like the shoreseines, boatseines, castnets, *rampanies* (huge shoreseines) and small meshed gillnets used to be engaged in the oil sardine fishery along the southwest coast. With the advent of purseseining in the late 1970s, first in Goa and then in Karnataka and Kerala, the traditional fishing systems began to lose their importance in the fisheries for the small pelagics in these states. The situation got further aggravated in the 1980s with the popularization of the ringseines in Kerala and *Mattabala* (a variant of the ringseine) in Karnataka, coupled with the steady growth of motorized fleets of traditional fishing craft in these states. The purseseines and the ringseines have almost replaced the *rampanies* (yendi) in Karnataka and the boatseines in Kerala.

Fishing season: The oil sardine fishery commences along the southwest coast soon after the outbreak of the southwest monsoon (June) and continues till March-April. Usually the fishery starts first in the south (9°N latitude, i.e., Quilon) and progresses to the north (l7°N latitude, i.e. , Ratnagiri), probably in sequence with the early upwelling in the southern area. The above cycle of events is repeated every year. The beginning of the fishery is marked by the entry of large sized fish in the advanced stages of maturity followed by the 0 year class. The commercial fishery is supported by the 0 and 1 year class fish. The success of the oil sardine fishery along the southwest coast depends mainly on the recruitment strength of the early juveniles of the size 5 cm to 10 cm during the post monsoon months. The juveniles begin to appear in the fishery from late August and form the mainstay of the fishery in the southern region, whereas in the northern region they begin to appear from late September onwards. The oil sardine always move in shoals, the size of the individual shoals being generally 2 m to 25m long and 1 m to 20m wide. The oil sardine shoals move at a speed of about 5km per hour and are known to descend to subsurface depths during daytime.

All India production*:* The average annual production of Indian oil sardine for the period of 1991 to 2012 was 3.14 lakh tonnes and contributed about 42.8% to total small pegagics (7.33 lakh tonnes), 21.8% to total pegagics (14.39 lakh tonnes) and 11.5% to total marine fish production (27.22 lakh tonnes). Oil sardine stock showed remarkable recovery after the population crash in 1994 (from a lowest of 0.46 lakh tonnes in 1994 to 7.20 lakh tonnes in 2012), with no parallel example in the India itself (Fig. 1; Table 3).

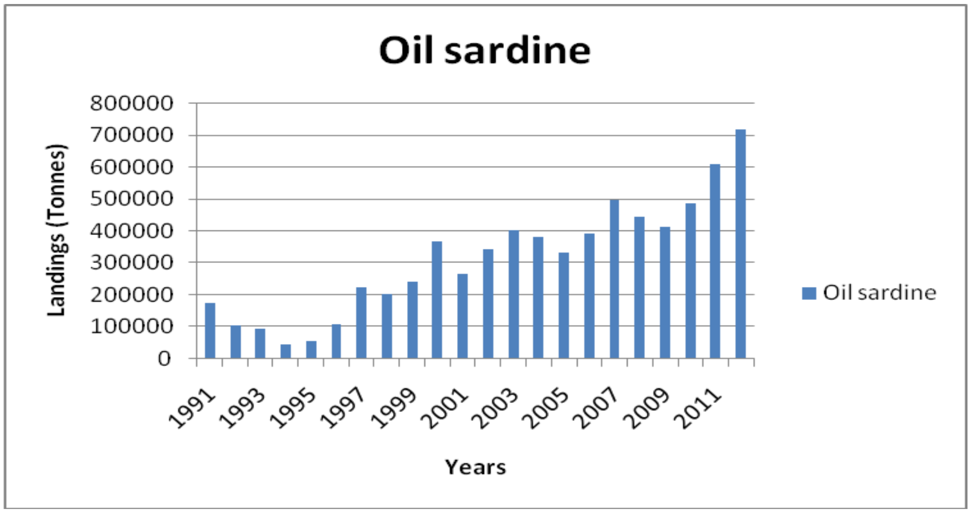

Fig. 1 All India landings of oil sardine during 1991-2012

Factors influencing fluctuations: The oil sardine fishery is known for its highly erratic and fluctuating behaviour. Hornell (1910) attributed the fluctuations to the changes in the production of diatoms, food availability to the fry and the prevalence or absence of favourable hydrological conditions. There is also a view that the fluctuations are related to the shifts in the migratory path of the fish, causing variations in the vulnerability of the stocks to fishing, owing to the limited range of the traditional fishing operations. Devanesan (1943) attributed the low catches to the overfishing of the immature fish, while Nair (1952) and Nair and Subrahmanian (1955) attributed the changes to the availability and abundance of the diatom *Fragilaria oceanica* in the inshore waters. Murty and Edelman (1970) stated that the intensity of the monsoon along the west coast of India above a critical value would be favourable for the enrichment of the sea not only with nutrients, but also with dissolved oxygen. Total number of fish in the population would not exceed the limits determined by the food resources and the rate of reproduction; if the numerical strength of a particular generation was large enough to utilize almost completely the food resources, the successive generations would become progressively weak in numbers, till the most dominant generation got reduced in its strength.

The success of a given year's fishery was found to be determined by the abundance of the 0-1 year-class during 2012-13. Dominance of the older groups over the younger ones could be attributed to the changes in the availability and poor recruitment into the fishery. Since rainfall during the spawning season has been found to determine spawning success, rainfall data could be used to differentiate changes in recruitment from changes in availability.

For spawning to be a success, the average rainfall per day during the peak spawning season (mostly June to August) should be 30 mm. Spawning takes place around the new moon, and its success depends on whether optimum rainfall prevails a week before and after the new moon day. Therefore, a number of factors in interaction with each other seems to determine the success of the fishery. The important factors include rainfall, availability and accessibility to the gear in operation, migratory pattern, survival of the eggs and larvae, and the intensity of upwelling.

Food and feeding habit: The adult oil sardine feed mainly on the diatoms, dinoflagellates, tintinnids and zooplankton. Among the diatoms, *Fragilaria oceanica, Pluerosigma, Coscinodiscus* and *Biddulphia*, and among the bluegreen algae *Trichodesmium thiebautii* are frequently met with in the diet. The dinophyceae consist of *Procenrrum, Ceratium* and *Perdinium.* Among the zooplankton, *Acrocalanus, Paracalanus, Oithona, Harpacticoids, Lucifer* and larval polychaetes are common. The juveniles are carnivorous while the postlarvae feed mainly on the diatoms. *F. oceanica* seems to be a good indicator of the abundance of the oil sardine stock in the coastal waters. During actual spawning, there seems to be cessation in feeding activity.

Age & growth and age composition: Divergent findings made by various authors about the age, growth rate and life span of the oil sardine reveal two distinctly different sets of results. The differences between the two sets are very sharp in the first year of age, but progressively narrow down at the 2 and 3 years of age. At the age of 4 years, the results agree each other very closely. A reanalysis of the length frequency data by means of the scatter diagram method of length frequency analysis (Devaraj *et al.*, 1997) confirms the second category results (1 year= 146 mm, 2 year = 171 mm, 3 year= 186 mm and 4 year = 194 mm) to be the correct estimate of length at age in years, which also implies growth to be very rapid in the first year, but very slow subsequently.

Size at maturity fecundity spawning and broods per year class: The oil sardine attains sexual maturity at the age of one year at a length of 150 mm. The active spawners in the oozing condition measure 150 to 170 mm. The sexes are separate. In spent and recovering fish, the males could be distinguished by an externally visible muscular papilla in the cloaca while the females could be identified by the presence of a membranous papilla behind the anal opening. The sex ratio appears to vary. Some investigators found the females to be predominant upto the size at first maturity, but a reduction in sexwise segregation among the ripe fish, and equal representation of sex among the juveniles and spawners. Annigeri *et al. (1992)* indicated the dominance of the females in all the observation centres along the east and west coasts during 1984-88. The relative fecundity varies from 70 000 to 80000 ova in the 1 to 2 year old fish (the left ovary produces on an average 40 000 eggs and the right ovary 38 000 eggs), but on an average a female produces 48 000 eggs per batch. Fecundity is directly proportional to the weight of the ovary, which in turn is generally related to the size of the fish.

Gravid and spent fish and juveniles occur in the near shore waters off Kerala and Karnataka during June to August. Spawning has been observed at a distance of about 15 km from the shore along the 30 m isobath in the surface and column from Quilon to Karwar. Isolated cases of spawning in the near shore areas have been observed off Kasargod and off Cochin during July. Spawning usually takes place at night, a few days before and after the new moon days. According to Antony Raja (1973), a daily rainfall of 20 to 30 mm during June to August may indicate good recruitment. Seasons of feeble or severe rainfall may lead to a reduction in the spawning potential of the population, and consequent recruitment failures.

Although the spawning season is generally held to extend from June to October, there is reason to believe that spawning may commence in January and last till October, but the main spawning seems to last for only 3 to 6 months or exceptionally it may be over in just one month. The commencement and the duration of spawning seem to vary from year to year, as evident from the time of origin of the broods, traced from the analysis of the 1957-63 length frequency data for Mangalore.

Thus, within the total duration of spawning, whether it is one month or up to 6 months, spawning intensity is found to be more or less uniform without a definite break or peak. As a result of uniform spawning, only one brood is released during each spawning season. The longer the duration of spawning, the wider is the distribution of the modal lengths for the younger size groups of a given brood in the scatter diagram of modal analysis. As the brood grows to complete about one year of age, the scatter values tend to become narrower in distribution. Such a change in the nature of the distribution of the scatter values seems to result from two reasons: (I) faster growth of that section of the brood that is still in the O-year-class ; (2) abrupt fall in the growth rate of fish of the same brood, which have attained I-year of age.

Contrary to this finding of the existence of only a single brood per year-class, earlier studies seem to suggest each year-class comprising more than one brood. On the basis of the monthly length frequency curves for several years from commercial samples collected from 5 centres along the west coast, Banerji (1973) recognized two broods per year-class corresponding to the two spawnings, one in June to July and the other in July to August. Antony Raja (1967) observed the spawning season off Calicut to be June to October within which he surmised two major spawnings, one in late June - early July and the other in late July to early August, giving rise to two broods. He further contended that the first brood released in June to July faced less competition for food and space, and hence, grew much faster than the second one.

Shoaling and migration*:* Different types of surface and bottom shoals have been described by Balan (1961). The O-year-class migrate *en masse* from the offshore to the inshore areas simultaneously all over the sardine centres along the southwest coast towards the end of the southwest monsoon. The new recruits, after reaching the inshore areas, continue to get reinforced uninterruptedly through the entry of fresh recruits, inspite of heavy fishing pressure. With the warming up of the surface waters and the deepening of the thermocline in summer (March to May), the shoals gradually move back to the offshore areas, vacating first from the north and then from the southern centres, every year. Large scale tagging of oil sardine was carried out by the CMFRI from several centres on the east and west coasts of India during 1967-68 and 1968-69 (Prabhu and Venkatararnan, 1970). The recoveries were limited. Hence no definite conclusions could be drawn regarding the migration of this fish, but the limited recoveries revealed only local dispersal. A programme of intensive tagging of oil sardine is essential in view of the recent emergence of this species along the east coast in commercial terms.

Stock assessment and management: Banerji (1973) estimated the total annual oil sardine stock in the southwest coast for the 1958-67 period to be 440 000 mt, the average standing crop 210 000 mt , and the MSY 212 304 mt for the optimum effort of 64.065 million manhours as against the average annual yield of 174 356 mt for the effort of 55.195 million manhours. Based on acoustic and aerial surveys coupled with test fishing, the UNDP Pelagic Fisheries Project at Cochin estimated the annual standing stocks for the period 1972-77 to be 400 000 mt. Balan and Reghu (1979) also estimated the stock size to be about 400 000 mt. Annigeri *et al.* (1992), however, estimated the MSY to be 150000 mt against a mean biomass of 107 000 mt, indicating scope for increasing production, but they also stated that increasing the fishing effort to the MSY level was not desirable as it would decrease the returns per boat considerably to uneconomic levels.

Utilization*:* Owing to the increasing demand for oil sardine from the local and the interior markets and easy availability of ice and quick transportation facilities, a good amount of oil sardine catch is now consumed in fresh condition. However, during periods of glut, a portion of the catch is cured with salt and sundried. The oil sardine are rich in oil which is extracted for various industrial uses. After the extraction of the oil, the residue forms the guano which is used as valuable manure in plantation crops because of the high nitrogen and phosphate content. Sardine fishmeal is in great demand in the livestock and shrimp feed industry.

<u>Other sardines:</u>

Species composition: The species of *Sardinella* other than S. *longiceps* (oil sardine), other sardines constitute rainbow sardines *(Dussumieria acuta* and *D. hasselti)* and the lesser sardines, which support lucrative fisheries especially along the southeast and Kerala coasts. Out of the 15 species of *Sardinella* in the Indo-Pacific region, 12 occur in the Indian Ocean. The sardines are typical shoaling fish occurring within the 50 m isobath in the coastal waters. The species that constitute the major lesser sardine fisheries include *Sardinella albella,* S. *gibbosa,* S. *fimbriata,* S. *sirm,* S. *dayi,* S. *sindensis,* S. *melanura,* S. *clupeoides* and S. *jonesi.*

Distribution*:* The other sardines are tropical, occurring along the coasts of Arabia, Red Sea, Madagascar, India, Sri Lanka, Malaysia, Singapore, Philippines, Australia and China. Along the Indian coast, while a few species are dominant in one region, a few other species are dominant in the other. In the Goa-Karnataka region (Konkan coast), S. *gibbosa, S.dayi, S.fimbriata* and S. *albella* are quite abundant. In Kerala, S. *gibbosa,* S. *sindensis* and S. *sirm* dominate the lesser sardines, while the lesser known species such as S. *clupeiodes, S.fimbriata,* S. *melanura* aod S. *jonesi* occur occasionally. S. *albella* and S. *gibbosa* are dominant in the Palk Bay and the Gulf of Mannar while S. *sirm* are limited to the peninsular tip between Vizhinjam and Tuticorin. S. *gibbosa,* S. *albella,* S. *dayi,* S. *sirm,* S. *clupeoides,* S. *fimbriata* aod S. *gibbosa* are abundant in the central region of the east coast.

Means of exploitation*:* The traditional non-motorized and motorized craft as well as the mechanized craft are employed in the lesser sardine fisheries. While the dugout and plankbuilt craft are used in the inshore waters, the purseseiners, gillnetters and trawlers are employed in the grounds extending upto the 42 m to 60 m isobath. The most widely used gears in the southwest coast include the boatseines, ringseines, purseseines and gillnets. The purseseines, which replaced the rampani in Karnataka, enhanced the lesser sardine catch in this state considerably. The trawlers operating in the nearshore grounds upto the 40 m isobath also land sardines in considerable quantities along the Karnataka coast. Small meshed gillnet is the main gear for the lesser sardine fisheries in the southeast coast.

All India production: The average annual production of other sardines for the period of 1991 to 2012 was 1.0 lakh tonnes and contributed about 13.64% to total small pegagics (7.33 lakh tonnes), 6.94% to total pegagics (14.39 lakh tonnes). During 1991 to 2012 other sardines landings ranged from a low of 69129 tonnes to 149022 tonnes in 2012 and contributed about 3.67% to total marine fish production of about 27.22 lakh tonnes (Fig. 2; Table 3).

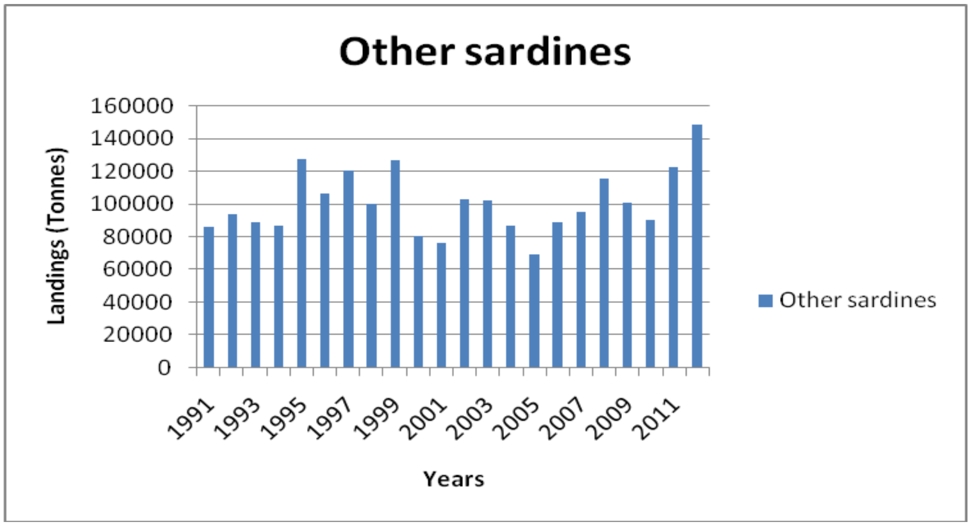

Fig. 2 All India landings of other sardines during 1991-2012

Food and feeding habits*:* The other sardines generally feed on a wide variety of plankton. There is considerable similarity in the food consumed by the different species. S. *gibbosa* feed on copepods, *Mysis, Lucifer,* prawn and crab larvae, fish eggs and larvae etc., while S. *albella* feed mainly on copepods, *Lucifer, Acetes, Mysis* , fish larvae, bivalve larvae etc. Both phytoplankton and copepods form the main food of S. f*imbriata,* while prawn and other crustacean larvae, *Acetes,* molluscan larvae etc. form the major food of S. *dayi.* The minor food items found in the other sardine diet include small penaeids, larval bivalves, decapod larvae, *Lucifer* and fish eggs.

In all the species of sardines, the gillrakers increase in number with size. For example, S. *albella* and S. *gibbosa* of 35 mm length possess only 45 and 44 gillrakers respectively, while at 164 mm, they possess 98 and 89 gillrakers respectively. S. f*imbriata* possess 43 and 81 gillrakers respectively, at the above lengths while S. *sirm* and S. *clupeoides* have only 26 and 42 gillrakers respectively at comparable lengths. Only S. *longiceps* possess the largest number of 145 and 258 gillrakers in the juvenile and adult stages respectively. A distinct relation is discernible between the number of gillrakers and the stock size, with species possessing large number of gillrakers developing into high volume stocks, particularly in upwelling areas taking advantage of the immense phytoplankton filtration capabilities. The only exception to this relation is that the oil sardine stock could not establish into a major stock in the Arabian upwelling area as most of the phytoplankton is lost into the mesopelagic realm where they support immense stocks of lantern fishes.

Size at maturity, fecundity and spawning*:* S. *gibbosa*, S. *albella,* S. *fimbriata* and S. *dayi* below 100 mm in total length are either indeterminate or immature with gonads in stage I or II of maturity. Fish measuring above 100 mm in length show varying degrees of sexual maturity. As the spawning season approaches, most of them in the length range of 100 mm to 120 mm attain maturing conditions, while those measuring above 120 mm in length become fully mature. The minimum size of S. *gibbosa* at maturity is l15 mm, but it varied from centre to centre, as in some localities it was found to be 139 mm. S. *fimbriata* attain sexual maturity at a length of 135 mm to 185 mm (Devaraj *et al.,* 1997), while S. *dayi* attain first maturity around 140 mm. The relative fecundity of S. *gibbosa* varied from 12786 to 41326.

The lesser sardines exhibit considerable variations in their spawning seasons depending on the species and regions. Although there is protracted spawning almost throughout year, peaks are evident, but individual fish seems to spawn only once in the case of S. *albella,* S. *gibbosa* and S. *fimbriata,* twice in the case of S. *longiceps* and thrice in the case of S. *sirm* within the same spawing season. Unlike the oil sardine, the other sardines seem to release 3 to 4 broods per year.

Stock assessment and management: The length at age of I year is 125 mm to 135mm in the case of S. *albella,* S. *gibbosa* and S. *fimbriata , 146* mm for S. *longiceps* and 170 mm for S. *sirm.* Based on the values of K, M and t_{max}, the growth of these sardines in relation to their life span is the fastest (K = 1 or more) in the first three species with a shorter life span of 2 years, but slow (K=0.53) in the last two species where the life span is three to four years. The direct relation between K and M is also obvious in these sardines. The high values of M for the stocks of S. *albella,* S. *gibbosa* and S. *fimbriata* are in tune with their fast growth in the first year of life and their role as the main forage (over 90%) of all epipelagic predators such as the seerfishes, dorabs and leather jackets in the Palk Bay and the seerfishes, tunas, bill fishes and sharks in the Gulf of Mannar.

The bulk of the lesser sardine catch consisted of the 0 year-class (90 %) particularly before 1965 in the Palk Bay and the Gulf of Mannar because of torch fishing with handnets of 8.5 mm mesh, boatseine with 16.5 mm mesh and shoreseines of 9 mm mesh (used during March to April for the new recruits), 12 mm (mesh used during May to June for the fast growing post-recruits) and 14 mm mesh (during July for the near adults). In locations like the Konkan, North Canara and Vizhinjam coasts, where gillnets (26 mm mesh) are also used, the 0 and 1 year-class es are present in equal proportions in the catches. In locations like Tuticorin and Malabar where the gill-nets constitute the major gear, nearly 95 % of the catches are of 1 year-class and the remaining 5 % are 0 year-class . As torch fishing and boatseining are not practised in the Palk Bay and the Gulf of Mannar after 1965, recruitment overfishing seems to have minimised in these regions.

According to George *et al.* (1977), the total annual stock of the lesser sardines is 280 000 mt comprising 20 000 mt in the Andamans, 30 000 mt in the northeast coast, 140 000 mt in the southeast coast, 80 000 mt in the southwest coast and 10 000 mt in the northwest coast and the MSY is 140000 mt (50% of the annual stock). However, according to Banerji (1973), the MSY for the 1958-67 period was only 53 000 mt.

Specific lesser sardine or rainbow sardine type of recordings have proved to be very scarce and erratic, being most frequently mixed with the shallow water mix as well as the whitebaits. The type of recordings recognized as the lesser sardines were often made in the area between 20m and 40m bottom depth. Fishing with pelagic trawls usually gave small catches, mainly of *S. fimbriala* and *D. hasselti* and occasionally S. *albella.* Seasonal southward migration of S. *fimbriala* and S. *albella* is evident from abundance shifting from the tip of the southwest coast (7°N latitude) in June-July to the east of Cape Comorin in the Gulf of Mannar (8°N latitude) in July-August. Similarly, *D. hasselti* move southwards from the Kasargode area (12°N latirude) in January to March through the (9° to 12°N latitude) and in May-June to the east of Cape Comorin (8°N latitude) in the Gulf of Mannar during July-August (.

Utilization: The lesser sardines are a source of cheap protein for the rural poor in the coastal regions. The sardines are consumed fresh in the coastal regions and transported with ice to the interior markets by road and train. Salted and sundried sardine products are sold in the hinterland states in India and also in countries like Sri Lanka and Hongkong. Smaller sardines are dried and used as important protein mix in the preparation of cattle, poultry, and shrimp feeds.

Anchovies and whitebaits:

Species composition: There are 35 species of anchovies and whitebaits reported from the Indian seas belong to five genera, viz., *Stolephorus, Coilia, Setipinna, Thryssa* and *Thrissina.* The whitebaits are the dominant component of the anchovy landings in India (Table 1). The whitebait fishery comprises 10 species. They are *Stolephorus devisi,* S. *bataviensis,* S. *heterolobus,* S. *buccaneeri,* S. *andhraensis,* S. *baganensis,* S. *commersoni,* S. *indicus,* S. *insularis* and S. *dubiosus.*

Distribution: The anchovies are widely distributed in the Indo-Pacific region. Whitebaits *(Stolephorus)* distributed along the southwest coast of India extending from Ratnagiri on the west coast (l7°N) to Tuticorin (8° 14'N) on the east coast mainly within 50 m depth. Whereas S. *devisi, S.baraviensis,* S. *heterolobus,* S. *baganensis* and S. *buccaneeri* form the fishery in the area between Ratnagiri and the Gulf of Mannar, S. *commersoni* and S. *indicus* form the fishery in Palk Bay and further north in the Bay of Bengal.

The grenadier anchovy, *Coilia dussumieri* are limited to the northwest coast, and to a limited extent, to the northeast coast.

Means of exploitation: The exploitation of the anchovies does not pose much problem as they are easily amenable to different kinds of fishing. The major gears employed in the fishery are the boatseines, shoreseines, bagnets and gillnets, operated mainly by the catamarans and plankbuilt boats, most of them fitted with outboard engines. The purseseines, ringseines and bottom trawls also land good quantities of anchovies. In the southeast and the southwest coasts, the most common gears exploiting the whitebaits include the boatseines (codend stretched mesh 10 mm) and the shoreseines (codend stretched mesh 10 to 20 mm). On the southwest coast south of Quilon, gillnets, known as *netholivala* (mesh 15 mm), are specially employed for the whitebaits during the main fishing season. In Kerala these gears are mainly operated from the catamarans and small plankbuilt boats, fitted with outboard motors. In Andhra Pradesh, however, large plankbuilt boats, known as *masula* boats, are employed in operating large shoreseines for the anchovies and other small pelagics. During October-March, when the shoals are distributed all along the coast in shallow waters at 15 m to 30 m depth, they can be effectively fished with high opening midwater trawls (codend mesh size: 15 mm). The purseseines (common stretched mesh at the bunt, 14 to 18 mm) are operating in Karnataka and Kerala from mechanized boats since the seventies and the ringseines (mini purseseines with a mesh of 8 mm) are operating from plankbuilt boats and dugout canoes fitted with outboard motors, since the mid eighties in southern Karnataka and northern Kerala. The operational depth of these gears ranges from 15 m to 50 m. Dispersed whitebait shoals can easily be aggregated by light attraction at night and caught by small purseseines.

All India production: An average annual landing of anchovies and whitebaits during 1991 to 2012 was 1.34 lakh tonnes, catch ranging from 0.95 lakh tonnes in 2006 to 1.65 lakh tonnes in 2008. Anchovies and whitebaits contributed about 18.28% to total small pegagics (7.33 lakh tonnes), 9.3% to total pegagics (14.39 lakh tonnes) and 4.92% to the overall marine fish production (27.22 lakh tonnes). The *Stolephorus* form 44.0% (59247 tonnes), *Thryssa* 26.86% (36112 tonnes), grenadier anchovy *C. dussumieri* 24.62 % (33540 tonnes) and *Setipinna* 4.1% (5615 tonnes) of the anchovies and whitebaits landings for the period of 1991 to 2012 (Fig. 3, 4; Table 3).

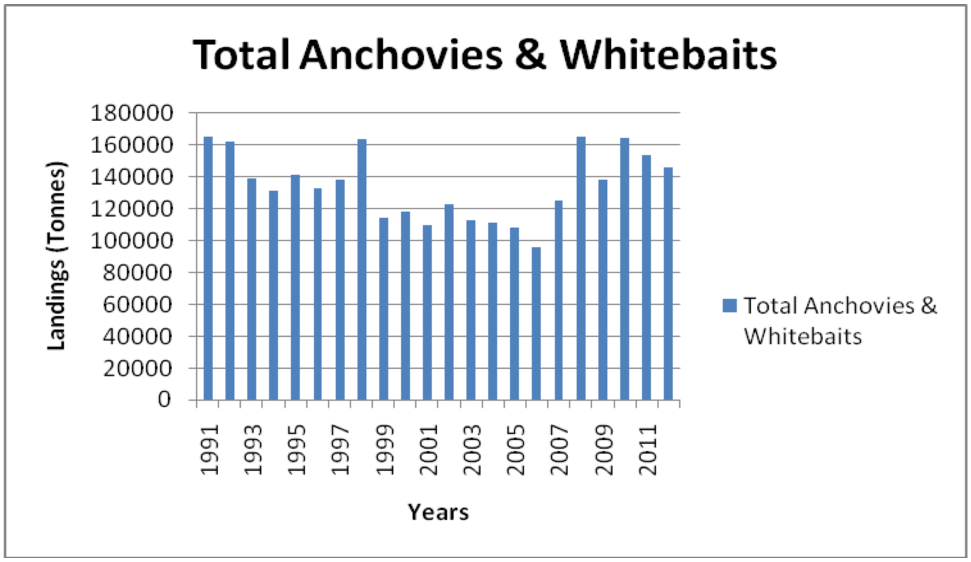

Fig. 3 All India landings of total anchovies & whitebaits during 1991-2012

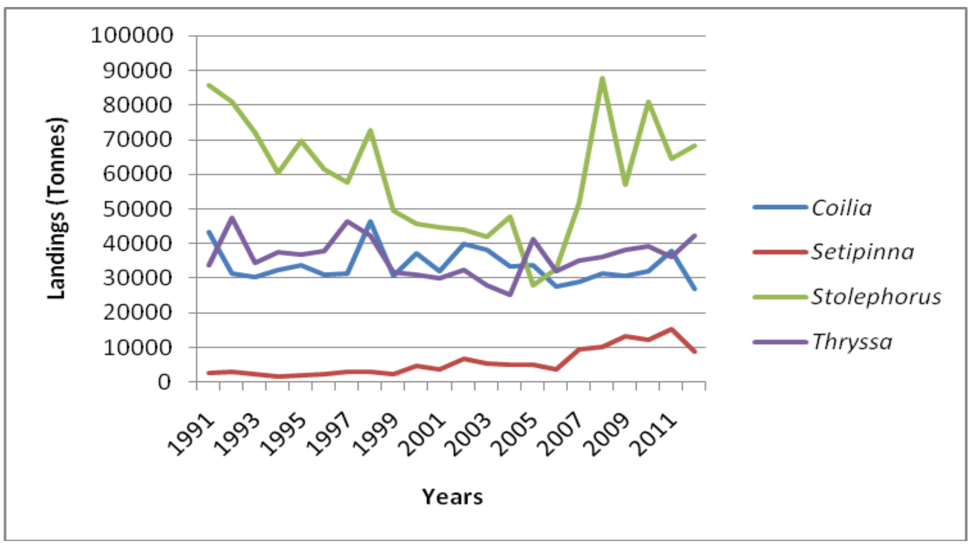

Fig. 4 All India landings of *Coilia*, *Setipinna*, *Stolephorus* & *Thryssa* during 1991-2012

Food and feeding: The whitebaits feed mainly on copepods, small bivalves and crustaceans. S. *devisi* occasionally feed on phytoplankton such as *Coscinodiscus.* The grenadier anchovy feed on *Acetes,* fish larvae, copepods, ostracods and prawn juveniles. *Thryssa* spp. feed on prawns, *Acetes,* polychaetes and fishes (Menon and George, 1975).

Size at maturity, fecundity and spawning: The spawning of the whitebaits occurs for about 10 months a year. However, there are periods of peak spawning for every species. S. *devisi* are multiple spawner, with spawning extending from November to July with peak intensity during October-February off Mangalore. The size at first maturity is around 62 mm. The total number of ripe ova in the mature ovaries of S. *devisi* varies from 670 to 3166 (Rao, 1988a). Along the southwest coast, the peak spawning of S. *baraviensis* takes place during February. The minimum size at first maturity is around 77 mm. The total number of ripe ova in the mature ovaries ranges from 972 to 2571 (Rao, 1988b). The fecundities of the other whitebaits are: S. *heterolobus:* 1000 to 2500; S. *bataviensis:* 5000 to 10000; S. *buccaneeri:* 7000 to 11000; S. *indicus:* 9000 to 14000. The grenadier anchovy spawn once in their life time, with peak spawning during April-June. The size at first maturity is 186 mm.

Migration*:* The whitebaits undertake seasonal migration along the southwest coast and the Gulf of Mannar in 4 distinct phases: (i) In October, when the northeast monsoon sets in, the shoals are discontinuously distributed in a narrow elongated band along the southwest coast from Mangalore to Cape Comorin. (ii) During November to February, the shoals form a continuous wide belt with a disruption between 11^0N and 12^0N. (iii) During March-April, the shoals break up and begin their southward migration, which continues till July. (iv) In August, the southward migration culminates, with the bulk of the stock migrating towards north in the east coast and piling up between Cape Comorin and the central Gulf of Mannar in the east coast. The migration of the whitebaits follows the surface currents of the northeast and the southwest monsoons. During the southwest monsoon, the currents flow southwards along the west coast; and north and northeastwards in the Gulf of Mannar; during the northeast monsoon, the current flows in the reverse direction.

Stock assessment and management: Stock assessment indicates that the increase in the production of the whitebaits from the present level will be marginal except in the case of S. *devisi* which is poorly exploited in both the coasts. However, in multispecies, multigear fisheries, could be only tentative, as there is no exclusive fishery for the whitebaits alone (Luther *et* al.,1992). While developing the anchovy fisheries further, the following fishing practices could be introduced: (I) high opening midwaler trawls for the grounds in the 15 m to 30 m depth during October to March, which is the major fishing season; (2) midwater trawls for the stocks that aggregate in the Gulf of Mannar during August to September and (3) chumming the shoals using light luring devices and catching them with small purseseines.

Utilization*:* Most of the anchovy catch is consumed in the fresh state except in times of glut when the surplus is dried and sent to interior markets. A small fraction of the fresh fish is used as baits in the hooks and line fishery. Improvements in cold storage facilities, introduction of artificial driers and canning in tomato sauce are some of the ways by which better utilization of anchovies could be ensured.

Indian mackerel:

Distribution: The Indian mackerel, *Rastrelliger kanagurta*, distributed widely in the entire Indo-Pacific region, constitute the mainstay of the mackerel fishery in this region. In India, *R. kanagurta* are widely distributed along both the coasts, with very high concentrations along the southwest coast. *R. brachysoma*, occurring in the Andaman waters contribute very little to the fishery while *R. faughni* has been reported to occur only very rarely along the southeast coast of India. Nearly 90% of the world production of the Indian mackerel *(R. kanagurta)* is contributed by India.

Means of exploitation: The major fishing craft engaged in the mackerel fishery include the motorized and nonmotorized catamarans, plankbuilt boats , dugout canoes, purseseiners and trawlers. The common gears employed include the shoreseines, boatseines, gillnels, hooks & lines, ringseines, purseseines and trawls.

All India Production: The average annual production of the Indian mackerel was 1.75 lakh tonnes and characterized wide fluctuations as evident from the catch records of the past 22 years (1991 to 2012), the production ranged from 0.9 lakh tonnes in 2001 to 2.78 lakh tonnes in 2011 (Fig. 5). Contribution of the mackerel was 6.42 % to the average annual marine fish production (27.22 lakh tonnes), 12.6% to total pegagics (14.39 lakh tonnes) and 23.87% to total small pegagics (7.33 lakh tonnes) during 1991 to 2012 (Fig. 5; Table 3).

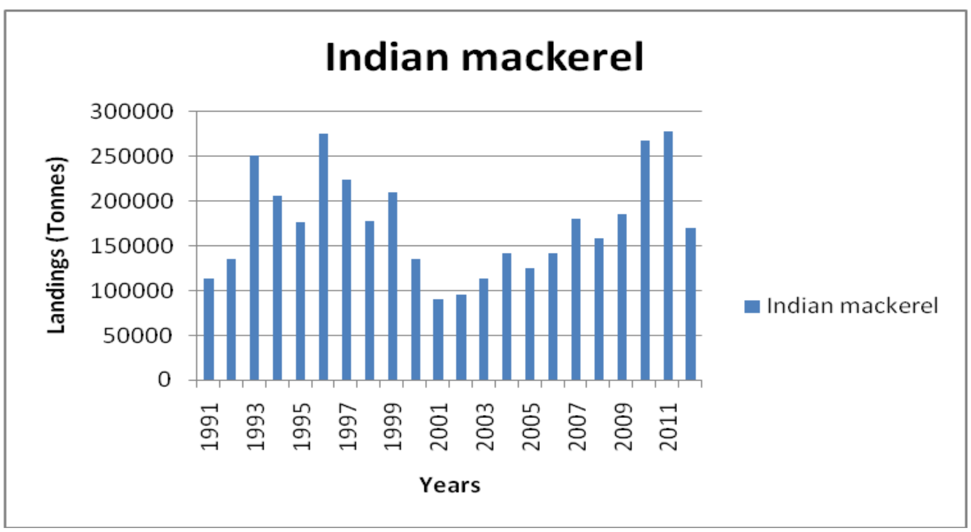

Fig. 5 All India landings of Indian mackerel during 1991-2012

Food and feeding: The Indian mackerel feed primarily on the zooplankton at the juvenile stages and mainly on the phytoplankton in the adult stages (Noble *et al.*, 1992). The most common food items are the diatoms, dinoflagellates, copepods, cladocerans, mysids etc. The intensity of feeding is very high in maturing and spent mackerel, but low in the spawners. Along certain areas off the west coast, two feeding maxima have been observed: one in October to December and the other in March to April when the fat content also increases appreciably. It is noteworthy that the feeding maxima are followed by the periods of brood release in January to February and April to May respectively.

Size at maturity fecundity and spawning: The size at first maturity ranges from 184 mm to 225 mm in total length, depending on the locations and the annual variations in maturation (Devaraj *et al.,* 1997). Along the southwest coast, spawning is protracted, with definite peaks in different localities within the extended season of February to September. Surveys by the Pelagic Fisheries Project (Anon., 1976) found mackerel larvae in great abundance during March to August along the southwest coast. Along the east coast, spawning extends from October-November to April-May. The occurrence of mackerel larvae all along the Indian coast suggests spawning along the entire coast. Observations by Luther (1973) reveal that the Indian mackerel spawn in succession, releasing the eggs in batches and spawning of mackerel takes place mostly in the night. The ripe ovary has two distinct batches of ova, the maturing and ripe ones. During each spawning season, an individual mackerel spawns two batches of eggs in quick succession. However, the number of broods per year-class of the west coast stock is limited in most of the years to just one (February to May) and rarely to two (February to May and October to November). Therefore, the two distinct batches of ova per fish cannot be directly related to the number of broods, separated from each other by a long duration of over five months. Instead, the number of broods may be related to the number of spawning peaks within a spawning season, each peak giving rise to a brood.

Devanesan and John (1940) estimated an average fecundity of 94 000 eggs. Rao (1967) found the absolute fecundity to be 110 000 eggs in 3 successive size groups in mackerel of 228 mm to 232 mm total length. Mackerel larvae and postlarvae have been collected along the southwest coast between 7°N and 12°N latitude at depths ranging from 10 to 200 metres. Evidently, the spawning takes place in the same grounds where the adults are distributed.

Stock assessment and management: The values of growth parameters of the mackerel vary widely between different areas, possibly due to the variations in the biotic and abiotic factors. Nevertheless, the growth coefficients have been found to be quite high for all the locations studied. It appears that the mackerel becomes physiologically old at 1.5 to 2 years. In spite of the variations in the basic input data used by different authors during different time periods, there is a surprising uniformity in the conclusions arrived regarding the stock size and the optimum yield.

Utilization: A good quantity of mackerel is consumed in fresh conditions along the coastal and nearby areas. During glut conditions the surplus catch is salted, sundried and sent to the interior markets. Export of frozen mackerel to the South East Asian countries seems possible, considering the surplus catches in certain years.

Half beaks & full beaks:

Belonids and Hemiramphids are commonly known as half beaks & full beaks supports a seasonal fishery along Tamil Nadu coast. They are exclusively exploited by a particular type of drift gill net. There are eight species of fullbeaks belonging to four genera namely, *Ablennes spp.*, *Platybelone spp.*, *Strongylura spp.* and *Tylosurus spp.* and 23 species of halfbeaks belonging to 7 genera namely, *Dermogenys spp.*, *Euleptorhamphus spp.*, *Hemiramphus spp.*, *Hyporhamphus spp.*, *Oxyporhamphus spp.*, *Rhynchorhamphus spp.* and *Zenarchopterus spp.* are found to be distributed in Indian waters (Table 1). Off which four species of fullbeaks and two species of halfbeaks (*Hemiramphus spp.*) observed to support fishery. The average annual production of half beaks & full beaks for the period of 1991 to 2012 was 4579 tonnes, contributed about 0.61% to total small pegagics (7.33 lakh tonnes) and catches ranged from 2300 tonnes in 1993 to 7316 tonnes in 2000; since 2000 to 2012 it is showing decreasing trend (Fig. 6; Table 3).

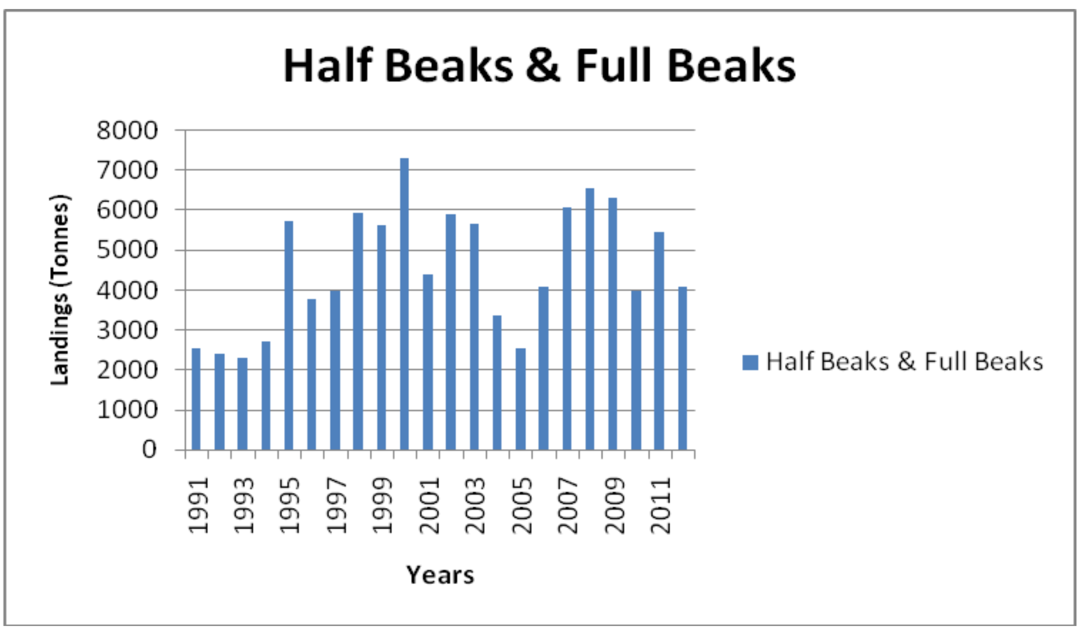

Fig. 6 All India landings of Half Beaks & Full Beaks during 1991-2012

Flying fishes:

Around 17 species of flying fishes belonging to four genera viz., *Cheilopogon spp*, *Cypselurus spp*, *Exocoetus spp*, *Hirundichthys spp* and *Parexocoetus spp* distributed along Indian coast. Seasonal flying fish fishery is limited to the Coramandal coast in Tamilnadu which is mainly supported by *Hirundichthys spp.* The fishery commences by the middle of May and lasts till the middle of July, though occasionally it extends up to the middle of August. The flyingfishes seldom appear in discoloured water, and hence, early onset of monsoon conditions resulting in the discolouration of the seawater with silt from the river discharges, forces the fish to migrate away from the inshore grounds, and the fishing season comes to an abrupt end. They are exclusively exploited by the scoopnets. The fish attain maturity at a size of 350 mm to 370 mm and spawn only a single batch of ova each season. The fecundity varies from 467100 eggs to 1369500 eggs for fish in the size range of 370 mm to 540 mm. The average annual production of flying fishes during 1991 to 2012 was 2518 tonnes, contributed about 0.34% to total small pegagics (7.33 lakh tonnes) and catches ranged from 173 in 1997 to 6236 in 2002; flying fishes showing decreasing trend since 2002 to 2012 (Fig. 7; Table 3).

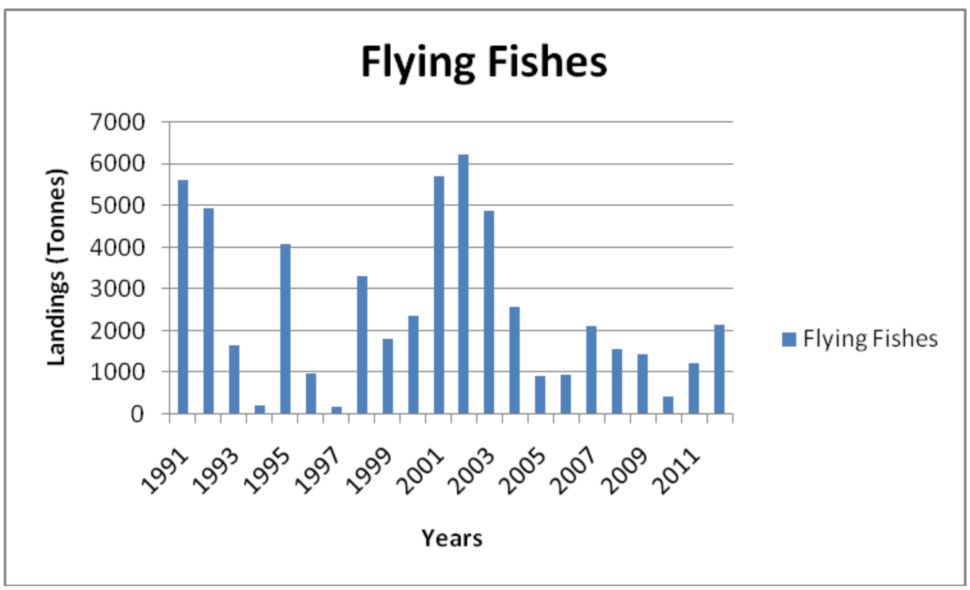

Fig. 7 All India landings of Flying fishes during 1991-2012

Unicorn cod:

The unicorn cod (*Bregmoceros mcclellandi*)) forms a coastal fishery along the Maharashtra coast and fishery starts in the post monsoon (October) and closes by March due to dwelling catches. It has been reported in good concentration in deep scattering layer along Bombay to Ratnagiri area. Unicorn cod is an important link in food chains of many commercially important species such as sciaenids, polynemids and Bombay duck. The average annual landing of unicorn cod for the period of 1991 to 2012 was 637 tonnes. The landings have decreased from 6880 tonnes per year during 1950-54 to 637 tonnes per year during 1991-2012. Over last 3 years unicorn cod showed increasing trend and production increased from 341 tonnes during 2010 to 1081 during 2012 (Fig. 8; Table 3).

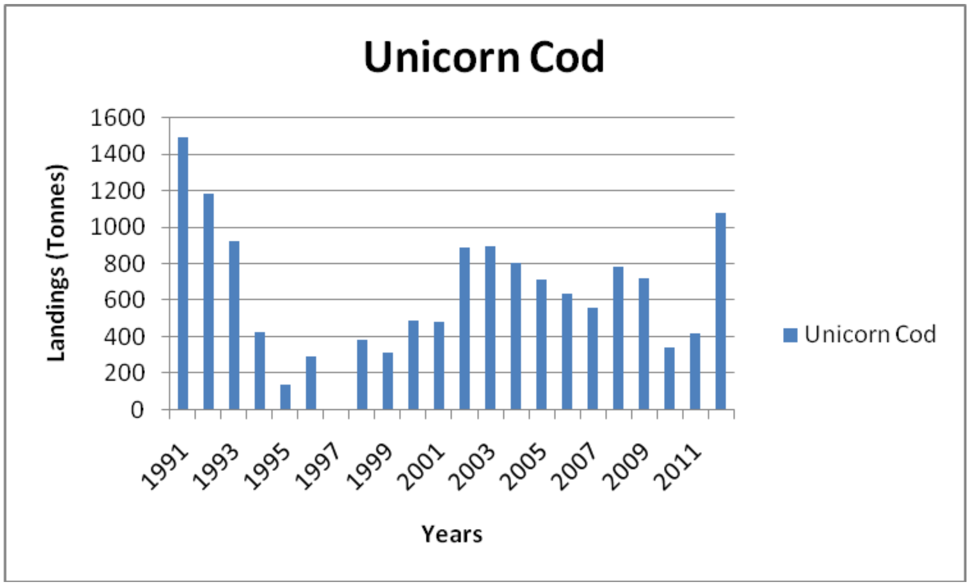

Fig. 8 All India landings of Unicorn cod during 1991-2012

Production trends of small pelagics in relation to pelagics and total marine:

Over the past twenty-two years, marine fish production in India has been increasing progressively from 22.42 lakh tonnes in 1991 to 39.48 lakh tonnes in 2012 (Fig.11; 12). The small pelagic catches increased from 4.74 lakh tonnes in 1994 to 11.92 lakh tonnes in 2012 (Fig. 9, 10; Table 3), registering a threefold increase. Although the marine fish production increased by 76% and small pelagic catches increased by 151%, in last 22 years, the growth rate in the production of pelagic fisheries has been conspicuously higher than that of the overall production (Table 3).

The small pelagics have been the mainstay of the pelagic catches consistently. During 1991-2012, the small pelagics constituted about 50.9% of the total pelagic catches (with the larger pelagics forming the remaining 49%) and 26.94% of the total marine fish production. Although the share of the small pelagics in the total pelagics over the past 22 years, showed increasing trend, from 43% in 1994 to 55.8% during 2012. The small pelagics of commercial bearing are mainly the oil sardine, other sardines, anchovies and whitebaits and Indian mackerel, together contributed 99.41 % to the small pelagics and remaining 0.59% by half beaks and full beaks, flying fishes, other mackerels and unicorn cod. Trends in their average annual production through the successive 22 year periods in the past dealt with in Table 3.

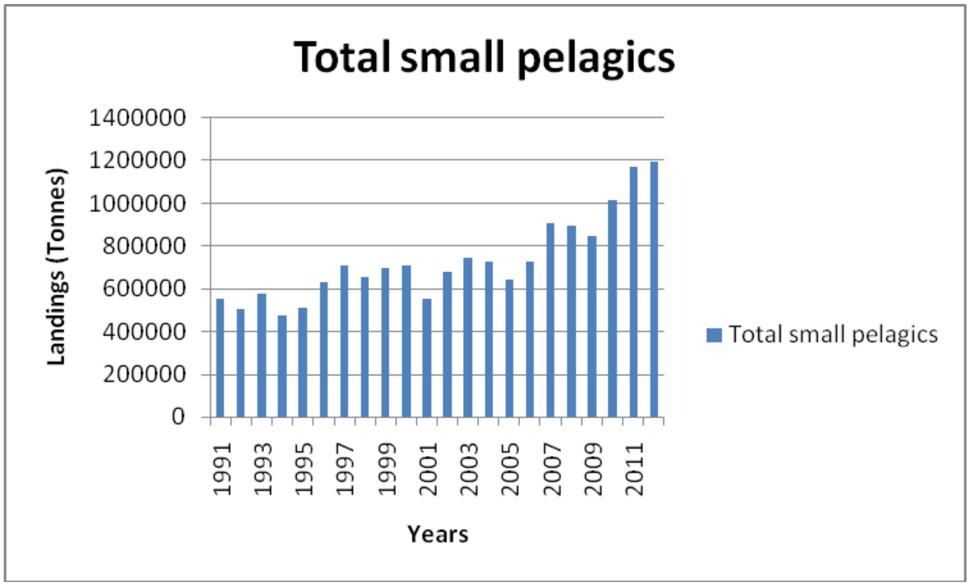

Fig. 9 All India landings of Total small pelagics during 1991-2012

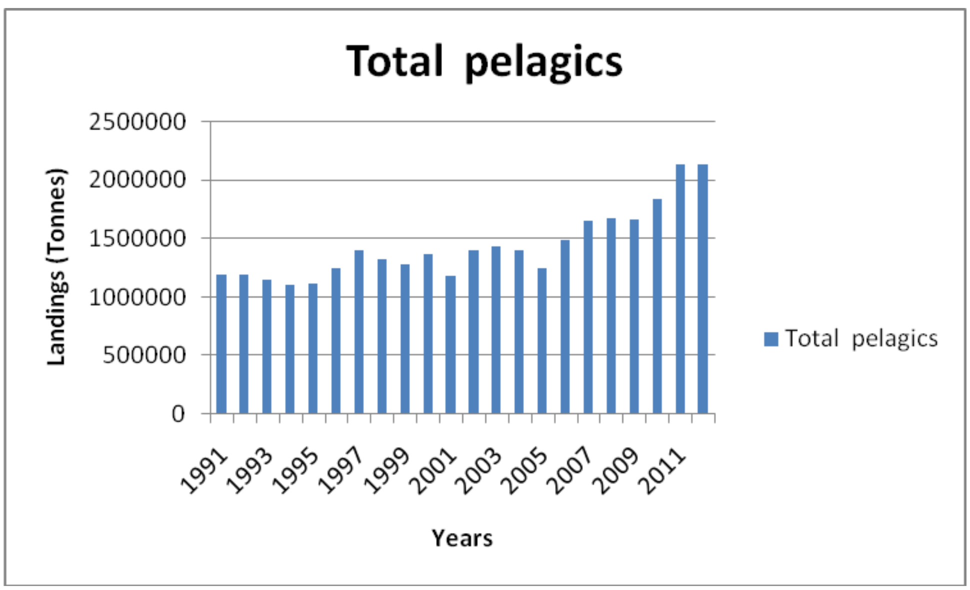

Fig. 10 All India landings of Total pelagics during 1991-2012

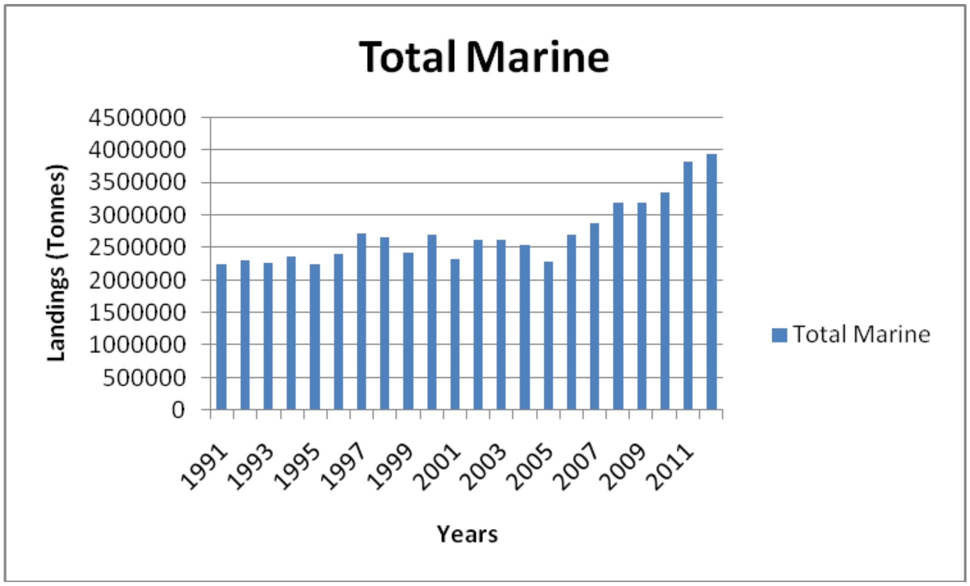

Fig. 11 All India landings of Total marine during 1991-2012

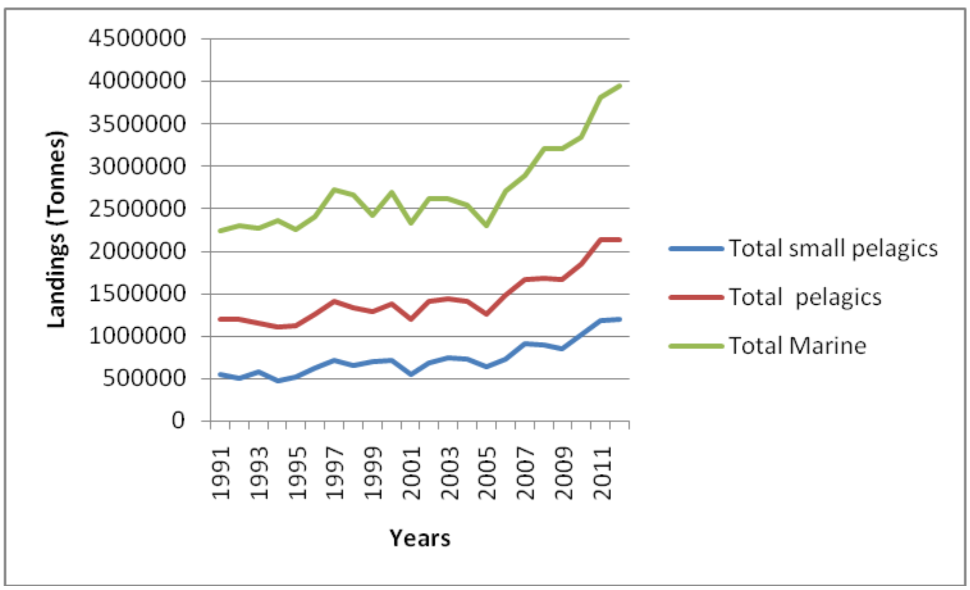

Fig. 12 All India landings of total marine, total pelagics & total small pelagics during 1991-2012

Table 3 Estimated small pelagic finfish landings (tonnes) during 1991-2012

Name of fish	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
Oil sardine	176887	104062	95385	46814	56633	110346	223879	203909	240978	367187	267790	344103	403952
Other sardines	86317	94094	88781	87148	127905	106924	120412	100059	127053	80686	76374	102885	102394
Anchovies	90	0	0	0	0	0	0	4	1	0	0	0	0
Coilia	43066	31360	30164	32327	33545	30986	31293	46293	30537	36911	31955	39760	37949
Setipinna	2410	2748	2359	1546	1771	2316	2871	2805	2314	4601	3445	6556	5371
Stolephorus	85526	80774	71925	60298	69486	61392	57479	72637	49543	45534	44539	44057	41909
Thrissina	3	0	5	8	0	146	19	5	156	31	1	0	0
Thryssa	33917	47367	34302	37365	36839	37944	46358	42231	31547	30904	30042	32229	27894
Anchovies & whitebaits total	165012	162249	138755	131544	141641	132784	138020	163971	114098	117981	109982	122602	113123
Half Beaks & Full Beaks	2543	2398	2300	2718	5747	3783	3988	5926	5634	7316	4378	5922	5649
Flying Fishes	5619	4929	1654	219	4090	997	173	3320	1798	2377	5724	6236	4881
Indian mackerel	113658	135033	251141	205844	176749	275677	223682	177172	209741	134556	90134	95573	113439
Other mackerels	17	1	5	22	81	17	18	4	26	0	0	19	5
Unicorn Cod	1492	1188	929	430	139	297	0	386	314	492	482	891	900
Small pelagics total	**551545**	**503954**	**578950**	**474739**	**512985**	**630825**	**710172**	**654747**	**699642**	**710595**	**554864**	**678231**	**744343**
Pelagics total	**1197237**	**1196014**	**1153104**	**1102079**	**1113408**	**1247842**	**1402304**	**1327593**	**1279564**	**1368449**	**1188028**	**1408677**	**1431728**
Marine total	**2242450**	**2299594**	**2278212**	**2359525**	**2258842**	**2414649**	**2726230**	**2669480**	**2418514**	**2700264**	**2326507**	**2623449**	**2620899**

Table 3 Estimated small pelagic finfish landings (tonnes) during 1991-2012

Name of fish	2004	2005	2006	2007	2008	2009	2010	2011	2012*	Average landings
Oil sardine	381448	334862	394598	496988	444593	414767	488205	609111	720270	314853
Other sardines	87065	69129	89041	95096	116101	101054	90846	122935	149022	100969
Coilia	33455	33760	27607	28760	31243	30518	31994	37629	26788	33540
Setipinna	5055	5090	3596	9441	10040	13036	12292	15239	8640	5615
Stolephorus	47773	27860	32704	51681	87687	56824	81008	64603	68197	59247
Thryssa	25249	41262	32000	34950	36228	38204	39281	36120	42246	36112
Anchovies & whitebaits total	111532	107972	95907	124832	165198	138582	164575	153591	145871	134537
Half Beaks & Full Beaks	3371	2553	4070	6062	6547	6308	3971	5474	4096	4579
Flying Fishes	2566	917	949	2117	1559	1458	431	1239	2157	2518
Indian mackerel	141774	125424	141918	180117	158913	185932	267250	278495	170297	175114
Other mackerels	0	0	1	0	14	196	3	8	113	25
Unicorn Cod	808	716	639	564	787	724	341	422	1081	637
Small pelagics total	**728564**	**641573**	**727123**	**905776**	**893712**	**849021**	**1015622**	**1171275**	**1192907**	**733234**
Pelagics total	**1405394**	**1255343**	**1486402**	**1656991**	**1679078**	**1668987**	**1839008**	**2133268**	**2133347**	**1439720**
Marine total	**2538105**	**2295490**	**2710988**	**2888461**	**3207205**	**3205453**	**3346658**	**3820206**	**3948938**	**2722732**

* Provisional estimate

(Source: CMFRI Annual Reports 1990-1991 to 2012-2013**)**

Climatic or environmental factors and its influence on small pelagic fisheries:

Since small pelagic fishes live near the air-water-interface, it is likely that climatically induced environmental effects will markedly affect production. Several climatic factors such as onset and intensity of monsoon, sunset activity, surface temperature, variations in patterns of coastal currents, sudden increase in salinity, dissolved oxygen, sinking of offshore waters/upwelling, sea level and availability of nutrients in coastal waters are believed to influence the distribution and abundance of small pelagic fishes. As small pelagics are very mobile and fast swimmers, they react immediately to changes in their physical environment. By performing either vertical or horizontal migration in order to remain in their preferred habitat, they avoid mortality caused by adverse conditions. Nonetheless, this is not always the case and some mass mortality of pelagic fish has been observed in upwelling ecosystems due to lack of oxygen or large-scale high concentration of hydrogen sulfide (Gammelsrod *et al*., 1998; Weeks *et al*., 2002). In the most common situation, environmental variability will only result in fish movements, which can be associated with changes in the aggregation pattern and will consequently affect the catchability and availability of the exploited fish stocks.

Small-scale environmental changes, like internal waves, rip or tide currents, etc., can result in rapid movement of pelagic fish. Diurnal changes in the vertical distribution of most pelagic fish form part of a normal cycle which usually consists of migration to the upper layers at the end of the day, associated with a lower level of aggregation than during the rest of the day; before sunset, fish start to aggregate in dense schools and then migrate to deeper layers (Neilson and Perry, 1990). These migrations are mainly driven by distributional changes in prey and predator species and by light levels that modify the mutual detection of the species. This diurnal cycle can be largely altered by any changes responsible for a modification in the visibility of the fish, such as the turbidity of the water column, the presence of bioluminescent plankton, or changes in light intensity of the sun and moon, depending on cloudiness or moon phase.

Along shore horizontal displacements of fish stocks are also observed in response to modifications in the environment, which can alter the regular pattern of seasonal migration. This occurs along Malabar Coast of India, where most *El Nino* events result in the displacement of the oil sardine and Indian mackerel stock. The success of pelagic fisheries is largely dependent on these short-term influences that mainly affect the catchability and availability of fish (Anthony and Forgarty, 1985; Fréon *et al.*, 2005). Temperature in the months prior to spawning was also found to influence the fecundity of pelagic fish. The processes responsible for changes in growth rate, fecundity, or mortality according to environmental factors are not always clearly identified, but they seem related to food abundance, intermingled with density-dependence.

Tham (1953) demonstrated that the abundance of catches of stolephorid anchovies (S. *heterolobus)* in the Singapore Straits were partially correlated with copepod abundance which, in turn, was correlated with rainfall, phosphate content of the sea water, and standing crop of phytoplankton. A positive correlation has been demonstrated between the recruitment of *Sardinella aurita* in the Mediterranean with sea temperature and rainfall (Ben-Tuvia, 1960). Similarly, Antony Raja (1972) showed that recruitment and catch rates of *Sardinella longiceps* were positively correlated with rainfall off the west coast of India.

Anthropogenic factors and its influence on small pelagic fisheries:

Fishing can affect both exploited and unexploited species that compete with exploited species for food. Fishing may trigger inter-decadal changes in small pelagic fish abundance or alter the changes from their natural course. Modeling by Silvert and Crawford (1988) supports this; they found that replacement of one pelagic fish species by another could be attributed to a combination of fishing and competition between predatory fish species for forage fish. Within a pelagic community, the removal of the dominant species should favor the subordinate species, provided that the latter is only lightly exploited. This line of thinking led to the targeting of anchovy when the commercially valuable sardine collapsed.

Other anthropogenic effects, such as contamination, modification of the quantity and quality of river discharges (more nutrients and contaminants, less natural debris) and the building of offshore structures (e.g., oil platforms), are less likely to directly affect small pelagic species because their habitat is usually extended and widely open to the ocean. Notable exceptions are those of closed or semi-closed areas like the Baltic Sea, where contamination and eutrophication play a major role in the ecosystem in general and on the small pelagic species in particular.

Conservation and management of small pelagic:

Small pelagic fishery resources of our country are dynamic and subject to fluctuations due to fishery dependent as well as fishery independent factors. Most of them move in large shoals and exhibit certain characteristic migratory pattern to the inshore or deeper areas for the purpose of feeding or breeding. In the course of such migration, large shoals enter the coastal waters and constitute the seasonal fishery. Towards the close of the season, a part of the stock that escapes from heavy fishing most probably migrate away from the fishing ground to offshore or deeper areas and thus becomes unavailable in traditional fishing grounds resulting an offseason for the fishery. This emigrant part forms the broodstock that contributes to new recruits to the coastal fishery in subsequent years and hence offshore fisheries development plan have to take this aspect also into consideration. This requires a sound knowledge based on the behavior of spawners of different small pelagics as well as their fecundity variations, which can be obtained through specialized studies.

The fishing vessel based stripping of ripe spanners of oil sardine and mackerel captured in the nets and releasing the eggs in the fishing grounds has been tried on an experimental scale. Such programmes in addition to existing restrictions on fishing for spawners and spawning grounds have to be strengthened. Fishing for oil sardine and mackerel by ringseines and purseseines (8-18 mm mesh size) has been observed to catch very small recruits of these fishes in the inshore waters especially during the monsoon period, which cause huge economic loss and may eventually cause growth over fishing in these stocks. The potential detrimental effects on the fish stocks due to large scale deployment of ring seines off Kerala coast have been highlighted (James, 1992a; Yhannan and Sivadas, 1993), but still gear remains popular among fishermen and there is huge increase in its fishing efficiency due to uncontrolled and unscientific increase in net dimensions and decrease in mesh size. Even though the 8 mm meshed ring seine net is meant for fishing the whitebaits, young recruits of sardine and mackerel measuring 40-80 mm are also caught in large quantities and hence these nets should be restricted solely to exploit whitebaits (*Stolephorus spp*.) by enacting suitable policy regulations. Further proliferation of ring seiners also needs to be checked urgently. Awareness creation among stakeholders against non-sustainable fishing practices with participatory management approach has become inevitable in fisheries management. Hence it has become necessary to review the status of exploited small pelagic fishery resources periodically and make periodic assessment of the small pelagic stocks, the fishing practices adopted and the juvenile and spawner components of the catches based on exploratory and research surveys. Based on this, need based management measure can be formulated either as input controls (restriction on fleet size, mesh size, closed areas or closed seasons) or output control (restriction on fishing for certain species, size of fish caught, total allowable catch limits etc.).

Conclusion:

Conclusions arrived based on present analysis are: At present level small pelagics almost optimally exploited. Mesh size – small size – particularly ring seine must be regulated (should be more than mackeral 18 mm and oil sardine 15 mm). Parent population need to be protected particularly during breeding season by fishing ban. Certain small pelagics socks such as flying fish and unicorn showed declining trend in it production, hence such fishery must be regularised.

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